

The University of Chicago

FLORAL DEVELOPMENT AND VAS-
CULAR ANATOMY OF THE FRUIT
OF RIBES AUREUM

A DISSERTATION SUBMITTED TO THE FACULTY
OF THE DIVISION OF THE BIOLOGICAL SCIENCES
IN CANDIDACY FOR THE DEGREE OF DOCTOR
OF PHILOSOPHY

DEPARTMENT OF BOTANY

1932

By
TSU KIANG YEN

Private Edition, Distributed by
THE UNIVERSITY OF CHICAGO LIBRARIES
CHICAGO, ILLINOIS

Reprinted from
THE BOTANICAL GAZETTE
Vol. 98, No. 1, 1936

The University of Chicago

FLORAL DEVELOPMENT AND VAS-
CULAR ANATOMY OF THE FRUIT
OF RIBES AUREUM

A DISSERTATION SUBMITTED TO THE FACULTY
OF THE DIVISION OF THE BIOLOGICAL SCIENCES
IN CANDIDACY FOR THE DEGREE OF DOCTOR
OF PHILOSOPHY

DEPARTMENT OF BOTANY
1932

By
TSU KIANG YEN

Private Edition, Distributed by
THE UNIVERSITY OF CHICAGO LIBRARIES
CHICAGO, ILLINOIS

Reprinted from
THE BOTANICAL GAZETTE
Vol. 98, No. 1, 1936



FLORAL DEVELOPMENT AND VASCULAR ANATOMY OF THE FRUIT OF *RIBES AUREUM*

TSU KIANG YEN

(WITH THIRTY-SEVEN FIGURES)

Introduction

Ribes aureum, the golden flowered currant, is closely related to *R. grossularia*, which GREW (7) has figured, showing the ovary as having two placentae, eight vascular bundles arranged as a ring in the fruit wall, and the enlarged cells of the seed coat. MALPIGHI (10) indicated that the structure of the gooseberry resembled the pomegranate and that each seed had a similar coating of juice cells. EICHLER (4) has given some of the taxonomical characters of *R. aureum*. VELENOVSKY (15, 16) mentioned the pericladium of *Ribes*. POHL (11) studied the fruit structures of many species of *Ribes*, and special attention was directed to the arillus of *R. aureum*. BUGNON (2) observed the trifascicular foliar trace of *R. sanguineum*, which resembles that of *R. aureum*. The present study of *R. aureum* deals with the development of the floral structures as well as with the anatomy of the fruit.

MATERIAL AND METHOD.—Material was collected on the campus of the University of Chicago from the autumn of 1929 until the autumn of 1932, and included series of buds and flowers, together with several stages in fruit development. The usual histological methods and stain technique were followed.

Investigation

DEVELOPMENT OF FLORAL ORGANS

The floral development of a number of plants belonging to the Rosoideae has been studied. GOFF (5, 6) studied the cherry, plum, apple, pear, and also called attention to the currant. He found that the flower primordia of the currant were just beginning to appear on July 8 at Madison, Wisconsin.

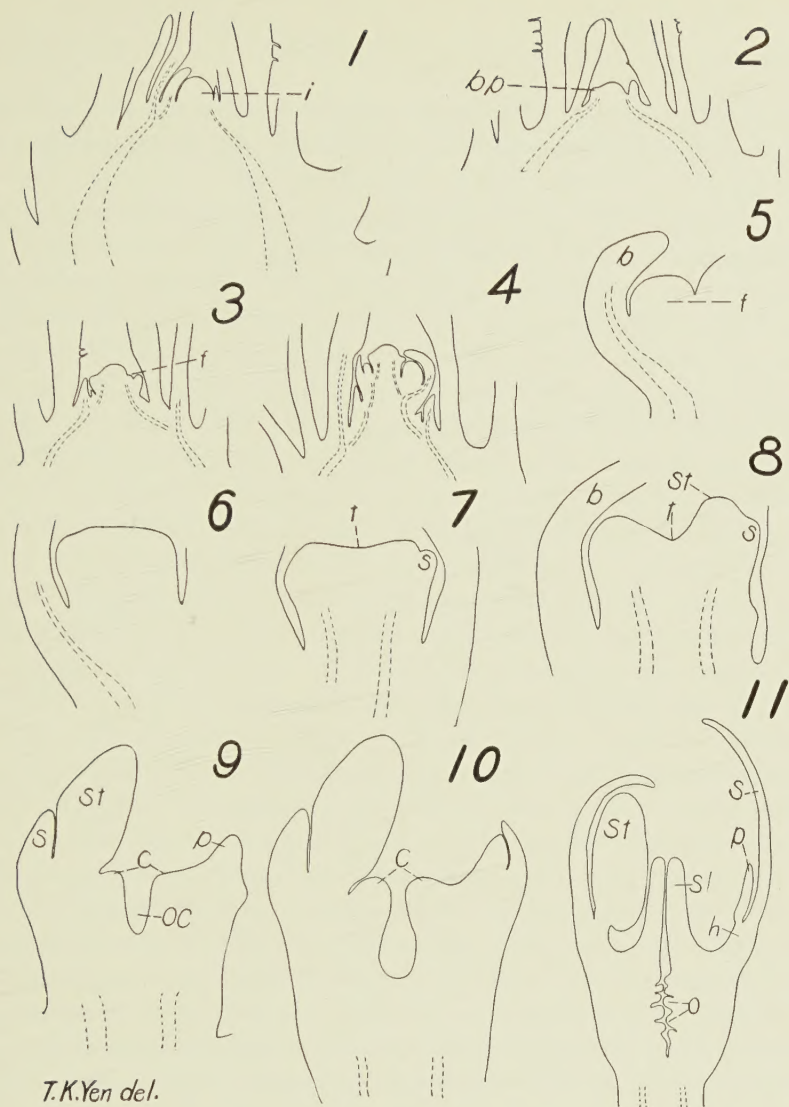
The differentiation of the floral primordia of *R. aureum* is some-

what similar to that of the apple, discussed in detail by BRADFORD (1), KRAUS (9), TUFTS and MORROW (14), and others. The outer bud scales of the dormant bud are five to seven cells in thickness; the epidermis is strongly cutinized, and on the adaxial surface many unicellular hairs are present. Nearly all the epidermal cells, except the hairs, contain tannin. A longitudinal section through a young bud collected August 2, 1931, shows a dome-shaped terminal meristematic portion surrounded by the primordia of spirally arranged bracts or scales. Below this tip the majority of the cells are parenchymatous, although it is possible to discern the structures usually present in a leaf bud (fig. 1).

From the terminal portion of the axis there is developed laterally the more or less ovoid primordium of a bract and soon thereafter a flower primordium arises in its axil. In like manner, bracts with floral primordia in their axils arise acropetally until each inflorescence is composed of six to eleven flower buds, the terminal one always remaining the smallest.

The first appearance of the individual flower is a dome-shaped protuberance (figs. 2-5). The growth of the young primordium is rather more rapid in circumference than in length. After reaching considerable size, elongation of the tip of the axis becomes progressively slower and finally ceases. Meanwhile the tissue near the periphery of the upper portion of the primordium grows more rapidly, and thus the primordium becomes much broadened (fig. 6).

SEPALS.—Five small protuberances are the first structures to arise from the outer circumference of the upper portion of the broadened axis. These are the sepal primordia (fig. 7). They grow into somewhat flattened, elongated structures (fig. 11). Differentiation and development of the epidermal cells are unlike on the two surfaces of the sepal. Those on the abaxial surface grow much larger, are covered by a thick cuticular layer, and some of them mature as well developed guard cells. Those of the adaxial surface have a very thin cuticular layer, are short and hair-like, and are responsible for the velvety appearance of the sepals (3, 13). The mesophyll tissue of the young sepal is composed of three or four layers of cells. They continue to divide until one or two more layers have been added. The cells of a layer which is next to the lower epidermis are rather



T.K.Yen del.

FIGS. 1-11.—Fig. 1, longisection of bud collected August 8, 1930; *i*, primordium of inflorescence. Fig. 2, same of bud collected August 8, 1932 showing differentiation of bract; *bp*, primordium of bract. Fig. 3, same of bud collected August 8, 1932 showing differentiation of flower primordium (*f*). Fig. 4, same of inflorescence collected August 22, 1930 showing later stage of fig. 3. Fig. 5, longisection through single flower primordium; *b*, bract; *f*, flower primordium. Fig. 6, same of flower primordium showing broadening. Fig. 7, same of flower primordium showing beginning of cup-like cavity brought about by slower growth of tip of axis than surrounding tissue; *s*, sepal primordium; *t*, tip of axis. Fig. 8, same of later stage than fig. 7 showing differentiation of stamen primordium (*st*). Fig. 9, later stage than fig. 8 showing differentiation of petal primordium (*p*); *c*, carpels; *oc*, ovarian cavity. Fig. 10, later stage than fig. 9 showing centripetal growth of tissue around ovarian cavity. Fig. 11, longisection of young flower bud; *o*, primordia of ovules; *st*, stamen; *sl*, young style; *h*, hypanthium; *p*, petal; *s*, sepal. (Dotted lines show vascular bundles.)

compactly arranged, and plastids may be found in them. The cells of the other layers become parenchymatous, with large intercellular spaces.

STAMENS.—Immediately after the appearance of the primordia of the sepals, a ring of tissue arises just inside them. Soon five protuberances differentiate from the inside of the ring, each being opposite a sepal primordium. They grow upward and soon exceed the sepals in length. These young stamen primordia are ball-like at first (fig. 8) but grow rapidly and elongate (fig. 9). Some of the hypodermal cells divide periclinally and give rise to a single layer of primary sporogenous cells and one layer of primary parietal cells. The wall cells divide several times, resulting in three layers of wall cells and one layer of tapetal cells. The sporogenous cells divide several times and are in the pollen mother cell stage during the winter.

The next spring, microspores are formed. The outermost layer of the wall differentiates as the endothecium. The tapetal cells grow rapidly, soon exceed the wall cells in size, and then begin to degenerate. Before the dehiscence of the anther, they are absorbed completely. The pollen grains are round and smooth, with many germ pores on the surface. Disintegration of the cells between the two loculi begins after the maturation of the pollen grains, and the anther opens as soon as the disintegration of the septum is completed.

PETALS.—The order of development of floral parts is the same as found by SCHERTZ (12) in *Scrophularia*. As soon as the sepals and the stamens have been laid down, the primordia of the petals begin to differentiate (fig. 9). The rudiments of the petals appear similar to those of the stamens and are differentiated from the distal portion of the same ridge of tissue, alternating with the stamens. Three distinct cycles of primordia are now discernible, the stamen cycle on the inside, that of sepals on the outside, and between these two the petal cycle (figs. 9, 10). At this stage the rudiments of the petals are much smaller than those of either the stamens or the sepals. The rounded protuberances soon become ellipsoidal in cross section, and with the exception of the narrower epidermal cells, there are no noted differences between the cells composing them. The basal part of the petal primordia is made up of three or four layers of mesophyll cells, while at its apex only one layer is present. The epidermal cells

of both dorsal and ventral surfaces develop into short, hair-like papillae. At first the petals grow slowly in length (fig. 11), but a short time before the opening of the flower, elongation takes place rapidly and they reach their full length, roofing over the more centrally placed structures. The undiverged basal portions of the sepals, petals, and stamens form a tube, the hypanthium.

CARPELS.—At approximately the time the primordia of stamens and petals begin their development, those of the two carpels are initiated. These appear first as two oppositely placed blunt protuberances just within the cycle of stamens arising from the margin of the cup-shaped receptacle and some distance from the tip of the main floral axis, which is still slowly elongating and enlarging. Soon the whole inner margin of the receptacle grows (figs. 7, 8) and is elevated actively, as is also the tip of the axis except at the central portion and two small areas adjacent to it. The continued elevation of these portions, together with that part of the receptacle lying exterior to them, results in the formation of two communicating carpellary cavities (fig. 9), roofed over by the upper portion of the carpels and surrounded laterally by the ovary walls, the abaxial portions of which, however, are indistinguishable from the tissue of the receptacle from which they remain completely undiverged. The two protuberances first to arise elongate much more rapidly than do the remaining portions of the ovary, and extend upward as development takes place, completely diverged from the remaining portions of the receptacle, sometimes referred to as the calyx tube, and also from each other, except at the base.

WALL OF FRUIT.—A cross section through a very young flower primordium shows practically no differentiation among the cells of the wall of the fruit. All are meristematic. Later procambial strands are readily visible, the vascular bundles appearing closer to the periphery of the receptacle than to the ovarian cavity. The difference between the development of the epidermal cells on the abaxial and adaxial surfaces of the fruit is striking. Those on the outside divide actively. Some of them differentiate as guard cells; others soon become thick walled. A cuticle of considerable thickness is deposited on the surface of the fruit. The epidermal cells on the inside of the ovary wall do not divide so actively, but elongate mainly tangential-

ly. A thin layer of cuticle is observable on them, but later the walls disintegrate and a sheath of gelatinous matter is present in the ripe fruit.

Some of the cells scattered among the parenchymatous tissue of the fruit wall grow more rapidly than others, and chloroplasts develop in them. The walls of these cells become thicker, but after pollination the chloroplasts gradually degenerate, and in a section of the ripe fruit no differences between these cells and the rest can be recognized.

PLACENTA AND OVULES.—As noted previously, there are two carpels, undiverged at their edges up to the time of pollination. These edges develop relatively little toward the center of the axis and thus appear as parietal placentae on opposite sides of the ovarian cavity. During development and maturation of the fruit, they increase in size appreciably. Several rows of ovules arise from them (fig. 11). The inner integument differentiates first but soon is overlapped by the more rapidly growing outer integument. An arillus develops from the funiculus of each ovule. No indication of the arillus can be observed until the diameter of the young fruit exceeds 2 mm. As the fruit grows from 2 to 3 mm. in diameter, the funiculus begins to increase both in number and in size of cells, finally almost enveloping the entire seed. In a section of a ripe fruit, the arillus appears as the pulp of disintegrated parenchymatous cells which fills up most of the space around the seeds. POHL (11) has described the arillus of this fruit.

STIGMA AND STYLE.—How the primordia of the carpels arise has been stated previously. A zone of cells surrounding the stylar canal remain meristematic and serve in part as conductive tissue. The epidermal cells of the most distal, stigmatic surface elongate into papillae. Some of the cells underlying the surface disintegrate a short time before blooming of the flower and form a mucilaginous mass at the surface.

After pollination, the upper portion of the style withers. Following this, two proliferating masses of tissue arise opposite each other on the inner portion of the base of the style. Each is derived from two adjacent carpels. The cells are at first parenchymatous but become suberized during the ripening of the fruit. The proliferations are not

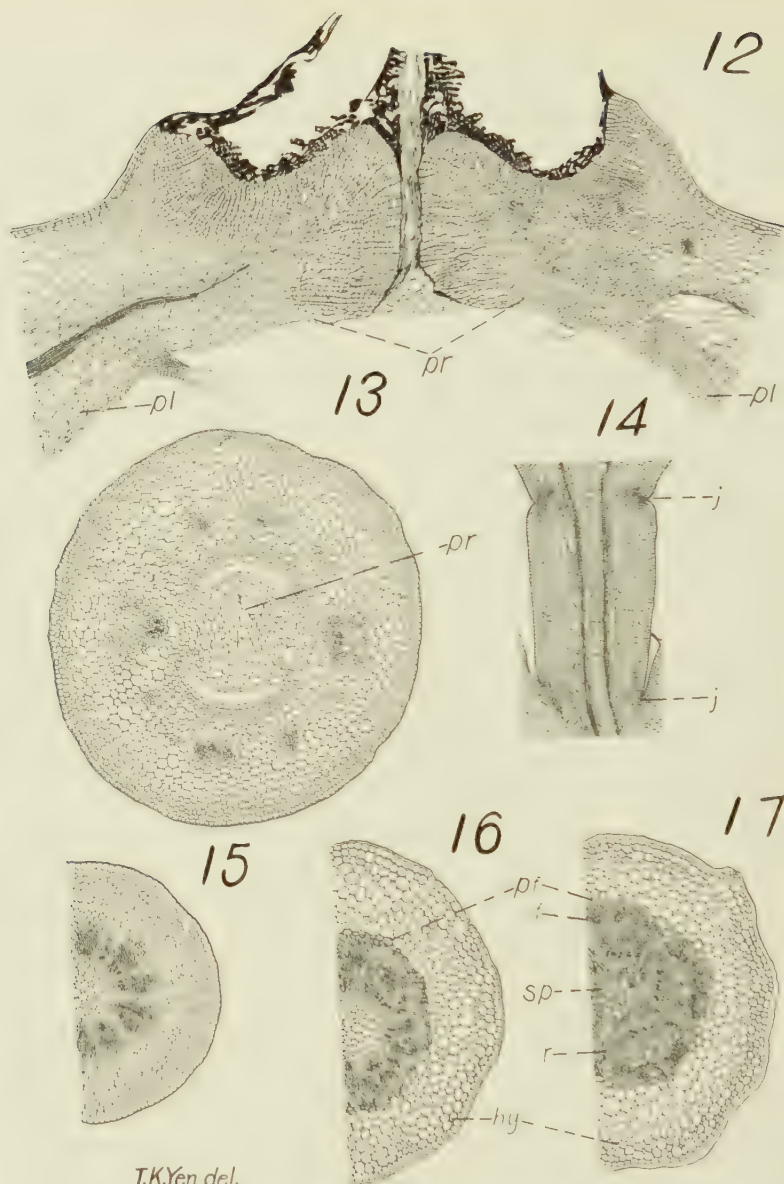
connected with the placentae, although they appear somewhat similar (fig. 13). These two masses of tissue develop rather late. In a very young fruit with a diameter of 3 mm., no trace of the proliferation is observable. When the fruit reaches a diameter of 4 mm., the cells on the inner margin of the base of the style begin to show divisions. The formation of these proliferations is completed in a few days. A cross section through the basal portion of a fruit 5 mm. in diameter shows the stylar cavity almost filled by them (fig. 12).

NECTARY.—The nectary is located in the groove between the hypanthium and the base of the style. In a transverse section of a young flower, it appears first as an active layer of cells next to the epidermis. These cells first divide tangentially but later both tangentially and radially. This activity results in the formation of a ring of tissue consisting of small cells with dense cytoplasm. In a ripe fruit the walls of these cells are suberized.

VASCULAR ANATOMY

BRAC T AND PEDICEL.—The vascular bundles in the axis below the base of the inflorescence are arranged in a ring (fig. 18); individual bundles at this point are not clearly distinguishable and are indefinite in number. At a higher level the ring is flattened out into an ellipsoid (fig. 19). Three bundles, one of which is situated at an extremity and the two others located near the middle of the ellipsoid, separate from the ring (fig. 20) and extend into the cortex. They are the main vascular bundles of the bract. This derivation of the three bundles of a bract is the same as in *Ribes sanguineum* as described by BUGNON (2). The lateral veins in the bract of *R. aureum* are more extensive and more profusely branched than is the midrib.

When these three bundles have diverged into the cortex, three gaps are left in the stelar ring (fig. 21), thus separating the ring into two small arcs on either side of the gap and a half circle opposite these two small arcs (figs. 20, 21). The two small arcs of vascular tissue soon diverge into the pedicel of the flower located in the axil of the bract. Above the point of divergence of the bract and the flower, the half ring of the main axis soon becomes a complete one (fig. 26), owing to the differentiation of additional xylem and phloem elements. In like manner this ring of vascular tissue is broken into the



T.K.Yen del.

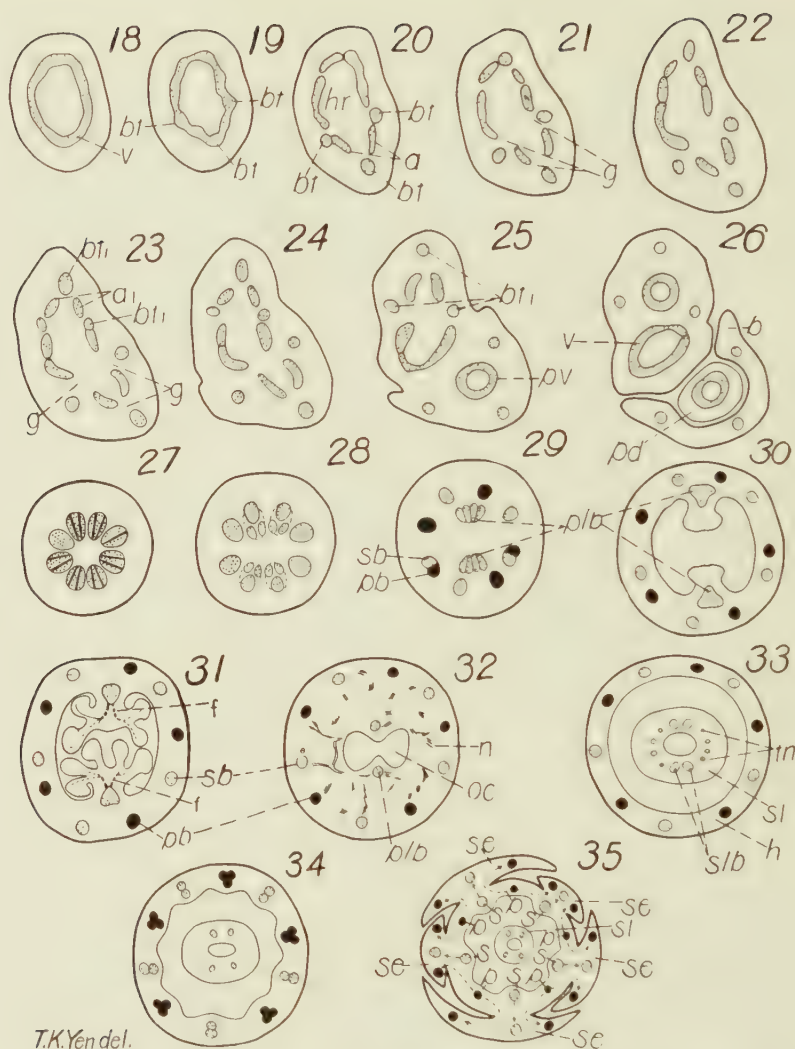
FIGS. 12-17.—Fig. 12, longitudinal view of upper portion of ripe fruit showing proliferations at basal portion of stylar canal; *pl*, placenta; *pr*, proliferations. Fig. 13, cross section of stylar region of young fruit with diameter of 5 mm., showing proliferations (*pr*). Fig. 14, longisection of young pedicel showing differentiation of two joint-like structures (*j*). Fig. 15, cross section of young pedicel showing parenchymatous tissues at that stage. Fig. 16, later stage than fig. 15 showing pericycle and phloem cells beginning to differentiate into fibers and the sclerotic condition of cells of hypodermis (*hy*); *pf*, pericyclic fibers; *f*, phloem fibers. Fig. 17, cross section through pedicel of ripe fruit; *sp*, sclerotic pith; *r*, sclerotic ray cells; *pf*, pericyclic fibers; *f*, phloem fibers.

half ring and two small arcs, which diverge into the flower pedicel, at each successive divergence of a bract and a flower (fig. 26). The differentiation of vascular elements in the pedicel of the flower above the point of divergence of the two small arcs soon closes the two gaps, separating the two arcs, and the ring of vascular tissue is complete.

The stellar ring of the pedicel is composed of eight collateral bundles arranged similarly to those in the stem (figs. 27, 37). Each bundle has from one to three rows of vessels separated by ray cells (fig. 27). Patches of smaller phloem cells separated by larger ray cells are present on the outside of each row of vessels.

BUNDLES OF BASAL PORTION OF FRUIT.—In that portion of the pedicel which flares out at the base of the fruit, the vascular bundles appear somewhat oblique. They are gradually extended toward the periphery of the fruit (figs. 28, 37), parenchymatous cells lying on all sides of them toward the central portion of the fruit as well as toward the outer epidermis. It is not possible to allocate this parenchymatous tissue either to a cortical or pith region since the cells appear so similar in general structure. The bundles are grouped into two crescent-shaped masses, each group composed of four bundles (figs. 28, 37).

PLACENTAL BUNDLES.—Of the four bundles composing the group just mentioned, the two central ones in turn are made up of three smaller bundles (figs. 27, 28). At a slightly higher level the central bundle of each of these groups of three is diverged slightly outward toward the periphery of the fruit, and of these two one is continued upward and finally terminates in a petal, the other in a sepal. The two remaining small bundles of each of these groups of three, making four in all (fig. 28), are diverged toward the carpellary cavity (fig. 29). They approach each other very closely and continue upward as the vascular system in one of the placentae (figs. 29–35). The other four bundles of the two groups lying at the tip of the crescents are not divided into smaller bundles at this level of the fruit (fig. 28), but extend toward the periphery of the fruit wall, so that at this level there are eight bundles in a circle at the periphery, and four placental bundles in two groups near the center (fig. 28). Each placental bundle is diverged into a number of lateral veins from which many vein-



T.K.Yen del.

FIGS. 18-35.—Fig. 18, diagram of cross section of base of axis of inflorescence showing vascular cylinder (*v*) as complete ring. Fig. 19, diagram of cross section of axis of inflorescence slightly above that of fig. 18 showing differentiation of bract traces (*bt*). Fig. 20, same, a little above fig. 19, showing vascular cylinder broken into the three traces of bract (*bt*), three gaps, two small arcs (*a*), and a half ring (*hr*). Fig. 21, same slightly above fig. 20, showing the three gaps (*g*). Fig. 22, bract traces extending toward periphery. Fig. 23, differentiation of another bract and floral primordium slightly above fig. 22; *bt*, bract traces of another bract; *al*, small arcs of another primordium. Fig. 24, diagram a little above fig. 23 showing traces extending more to periphery of cortex. Fig. 25, two small arcs of first flower primordium becoming a ring; *pv*, vascular ring of pedicel. Fig. 26, diagram of cross section through node of inflorescence axis showing bract (*b*), pedicel (*pd*), and complete vascular ring of axis (*v*). Fig. 27, cross sectional

lets are derived. These veinlets are the vascular bundles to the ovules (fig. 31). The lateral veins of a main placental bundle are arranged in two vertical rows parallel to each other. The veinlets of the two rows remain distinctly separate and each placenta is therefore recognizable by its venation, as it were, as consisting of two halves (fig. 31).

BUNDLES OF STAMENS, SEPALS, AND PETALS.—At a level slightly higher than that at which the placental bundles become definitely recognizable, two of the peripheral bundles located at the extremities of one of the crescent-shaped groups are divided to form two bundles each (fig. 29). Of the four bundles resulting, two finally terminate in the petals, two in the sepals. Thus ten vascular bundles are formed in a ring near the periphery of the wall of the receptacle (fig. 30). These are the primary bundles of the sepals, stamens, and petals. Each bundle may be branched to form one or more small bundles near the top of the fruit. These small branched bundles extend centripetally almost perpendicularly to the main bundles, diverging freely to form a fine network crowning the upper portion of the ovary (figs. 32, 37). The centripetal differentiation of these veinlets progresses almost to the ovarian cavity and a ring of bundles is completed, with the addition of the placental bundles, around this cavity (fig. 37).

In the upper portion of the hypanthium before the divergence of the sepals, petals, and stamens, the bundles are arranged in two con-

view of pedicel showing eight vascular bundles arranged in ring, six with three rows of vessels, one with two rows, and one with one row. Fig. 28, diagram of pedicel showing eight bundles arranged in two crescent-shaped groups with two bundles in middle of each group dividing into three bundles each. Fig. 29, diagram showing union of four small bundles into placental bundle (*plb*) and two bundles at either extremity of one of the crescents dividing to form two bundles each. Dotted bundles in outer ring of diagram are stamen bundles (*sb*) and black ones are petal bundles (*pb*). Fig. 30, cross sectional diagram through lower portion of fruit showing two placental bundles (*plb*) and ten primary vascular bundles. Fig. 31, diagram of cross section through middle of fruit showing two parallel rows of vascular bundles (*f*) derived from placental bundles; *sb*, stamen bundles; *pb*, petal bundle. Fig. 32, diagram of cross section through upper portion of fruit showing network of bundles (*n*), ovarian cavity (*oc*), and placental bundle (*plb*). Fig. 33, diagram of cross section through hypanthium (*h*); *sl*, style; *tn*, tips of bundles of network; *slb*, styler bundles. Fig. 34, cross section through upper portion of hypanthium showing divergence of bundles. Fig. 35, diagram through top of flower showing petals and stamens alternately arranged; *se*, sepals on outside, showing bundle derivation; *s*, stamens; *p*, petals; *sl*, style. Arrows show divergence of sepal bundles.

centric rings (fig. 34), those of the petals and stamens in an inner ring alternating with the sepal bundles. Five of the ten main bundles present here are common bundles of the stamens and sepals (fig. 34). These five usually do not branch until the middle part of the hypanthium is reached, where each branches into two (fig. 36),

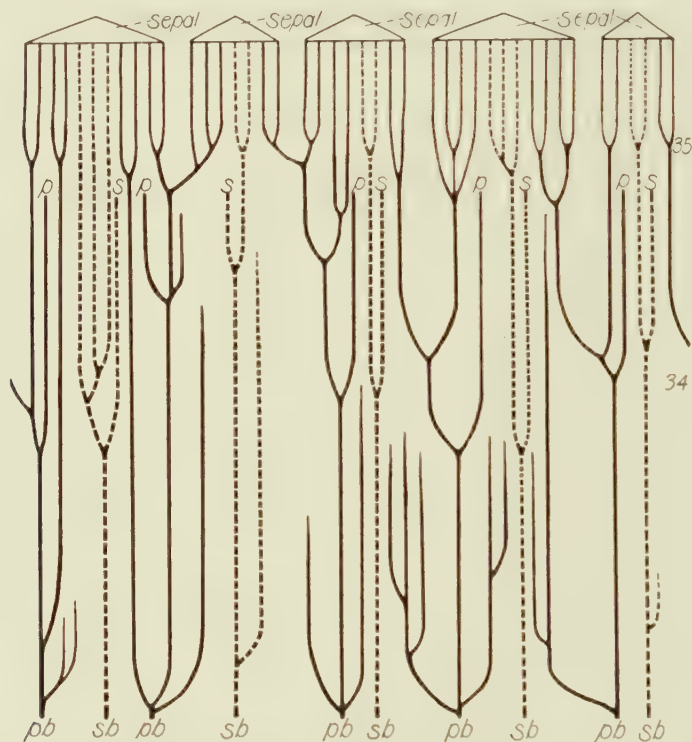


FIG. 36.—Diagram showing venation of petals (*p*), sepals, and stamens (*s*); *pb*, petal bundles; *sb*, stamen bundles.

one extending to the stamen, the other dividing again into two or occasionally more and extending to a sepal (figs. 35, 36). The single bundle which diverges into the stamen remains unbranched.

The other five main bundles terminate in the petals (figs. 34, 36). They are arranged alternately between the bundles which are diverged into the stamens, are occasionally rebranched just above the level of the network near the top of the ovary, and these branches

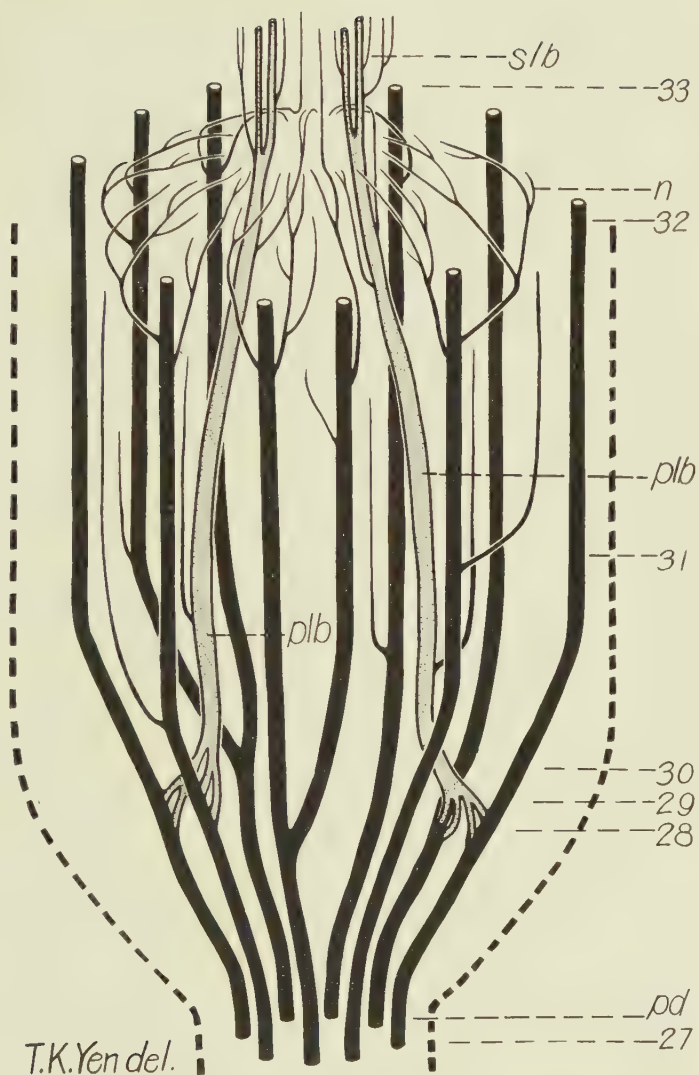


FIG. 37.—Diagram showing venation of a fruit: *s/b*, style bundles; *n*, network; *plb*, placental bundles; *pd*, pedicel. Small numbers at right of figs. 36 and 37 indicate places from which the cross section diagrams bearing similar numbers were made.

are diverged into the sepals. Each of these five main petal bundles is divided into two at a point half way up the calyx tube (fig. 36), one becoming the main vascular bundle of the petal. This bundle is re-branched into six or more veins; the other gives rise to two or more branches, each of which is divided into two veinlets which diverge into the lateral portions of either adjacent sepal (figs. 35, 36).

BUNDLES IN STYLE.—Near the base of the style the two placental bundles already described are diverged into two main bundles and several smaller ones. These small bundles are rebranched as a network in the tissue of ovarian walls. They extend through the entire length of the style and are divided into several small veinlets which are traceable almost to the tip of the stigma (fig. 35). Some veinlets other than those derived from the placental bundles are present on either side of the style. These are extensions of the branches from the network near the top of the fruit and are traceable for a short distance in the style above the ovary (fig. 33).

Comparing the floral and vascular anatomy of *Ribes aureum* with the apple (9) in the Rosaceae, the former seemingly represents an advance in the decreased number of stamens and carpels, in the lack of clear demarcation of the ovarian tissue from that of the receptacle, and in the failure of divergence of a distinct vascular supply for the carpels except as represented by the vascular system in the placentae and a portion of the vascular bundles of the styles.

Summary

1. Except for the terminal flower, each flower primordium of *Ribes aureum* arises in the axil of a bract. It is a dome-shaped protuberance at first but soon becomes cup-shaped owing to the lateral expansion of the axis.
2. The order of the floral development is sepals, stamens, petals, and carpels.
3. The carpels are undiverged at the bases and two virtually parietal placentae are present.
4. The inner integument of the ovule is initiated first but is soon overlapped by the outer one. After fertilization, the epidermal cells of the outer integument enlarge and become succulent.
5. The funiculus enlarges as an arillus, the cells of which disinte-

grate into a pulpy mass almost filling the space surrounding the seeds.

6. The two placenta-like proliferations derived from either side of the base of the stylar canal have no connection with the placentae.

7. Two joint-like structures are found at either end of the pedicel.

8. The vascular bundles of the pedicel are eight in number. They divide to form two crescent-shaped groups in the fruit wall, each of four bundles.

9. A placental bundle is derived from the two bundles at the center of each crescent. Each placental bundle gives rise to two vertical rows of veins which are parallel and remain distinctly separate.

10. Each stamen bundle is diverged into two, one of which extends to the sepal and divides again, the other to the stamen and is undivided.

11. Each petal bundle is alternate with a stamen bundle. It is divided into two, one extending into the petal where it is divided again into three bundles with many veinlets; the other is divided into two, one of each of these diverging into the outer portion of either adjacent sepal.

12. The bundles of each sepal are derived from three different origins, those in the center from a bundle common with the stamen bundle for some distance, and those on either side diverged from adjacent bundles terminating in the petals.

13. The bundles of the style are derived primarily from the placental bundles. A few small bundles are diverged upward from the network of bundles at the top of the ovary.

14. The vascular bundles in the fruit wall are arranged in a single ring, which makes impossible a classification of them into carpellary and toral bundles or a segregation of the parenchymatous cells surrounding them into pith and cortex.

LITERATURE CITED

1. BRADFORD, F. C., Fruit-bud development of the apple. Oregon Agr. Exp. Bull. 129. 1915.
2. BUGNON, P., Différenciation de la trace foliaire trifasciculée du *Ribes sanguineum*. Bull. Soc. Bot. France 73:1032-1038. 1926.
3. EAMES, A. J., and MACDANIELS, L. H., Introduction to plant anatomy. McGraw-Hill Book Co. 1925.
4. EICHLER, A. W., Blüthendiagramme. Leipzig. 1878.
5. GOFF, E. S., The origin and early development of the flowers in the cherry, plum, apple and pear. Wisconsin Agr. Exp. Sta. Rept. 1899.
6. ———. Investigation of flower buds. Wisconsin Agr. Exp. Sta. 18th Ann. Rept. 1901.
7. GREW, N., The anatomy of plants. London. 1682.
8. KRAUS, E. J., and RALSTON, G. S., The pollination of the pomaceous fruits. III. Gross vascular anatomy of the apple. Oregon Agr. Exp. Sta. Bull. 138. 1916.
9. KRAUS, E. J., Gross morphology of the apple. Oregon Agr. Exp. Sta. Res. Bull. 1. 1913.
10. MALPIGHI, M., Die Anatomie der Pflanzen. London. 1675 and 1679.
11. POHL, F., Zur Kenntnis unserer Beerenfrüchte. Beih. Bot. Centralbl. 39: 206-221. 1922.
12. SCHERTZ, F. M., Early development of floral organs and embryonic structures of *Scrophularia marylandica*. BOT. GAZ. 68:441-451. 1919.
13. SCHNARF, K., Beiträge zur Kenntnis des Blütenbaues von Alangium. Sitzungsber Acad. Wiss. Wien. 1 Abt. 131: 1922.
14. TUFTS, W. P., and MORROW, E. B., Fruit-bud differentiation in deciduous fruits. Hilgardia 1:3-15. 1925.
15. VELENOVSKY, J., Die gegliederten Blüten. Beih. Bot. Centralbl. 16:289-300. 1904.
16. ———. Vergleichende Morphologie der Pflanzen. III Teil. Prag. 1910.

